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ABSTRACT

This third in a series of six modules for a course titled Nondestructive Examination (NDE) Techniques II explains the principles of magnets and magnetic fields and how they are applied in magnetic particle testing, describes the theory and methods of magnetizing test specimens, describes the test equipment used, discusses the principles and reasons for demagnetization, and describes the applicability, advantages, and disadvantages of specific test methods. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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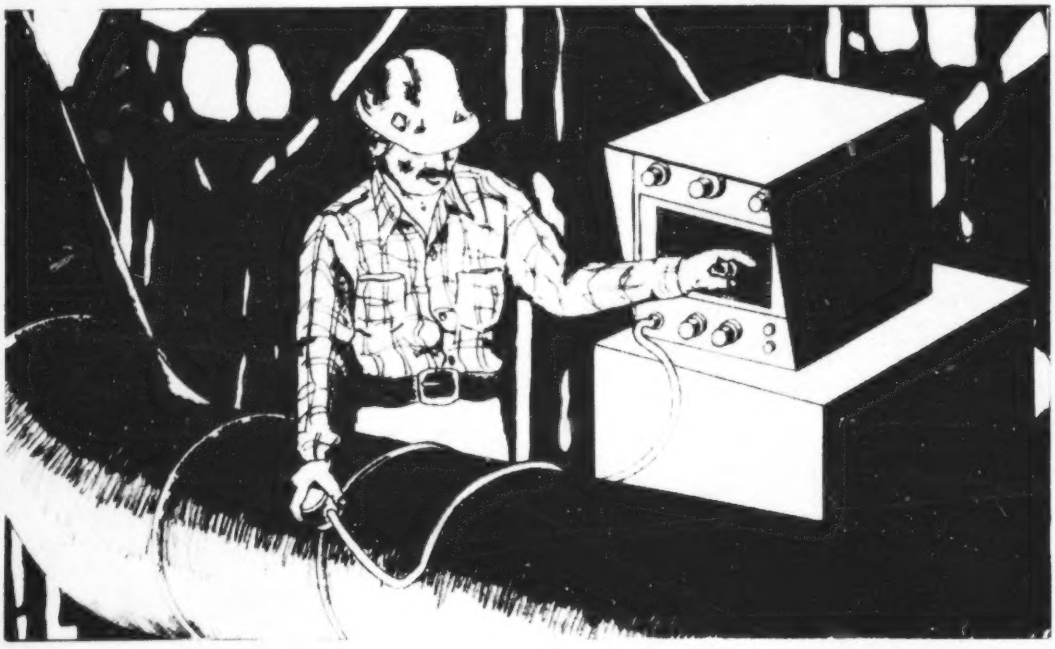
NUCLEAR TECHNOLOGY

COURSE 32 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II

MODULE 32-3 Fundamentals of Magnetic Particle Testing



CE 024 295

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 32 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II

Module 32-1 Fundamentals of Ultrasonic Testing
Module 32-2 Operation of Ultrasonic Test Equipment
Module 32-3 Fundamentals of Magnetic Particle Testing
Module 32-4 Operation of Magnetic Particle Test Equipment
Module 32-5 Fundamentals of Eddy Current Testing
Module 32-6 Operation of Eddy current Test Equipment

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This module was prepared for General Physics Corporation by Richard Groseclose, General Physics Corporation.

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1979

INTRODUCTION

One of the most widely used methods of nondestructively examining and evaluating materials, fabricated components and weldments, is magnetic particle testing. The QA/QC technician may encounter or be responsible for performing, evaluating, or witnessing magnetic particle tests in a number of various settings and activities, such as mechanical equipment manufacture and installation, piping fabrication and installation, equipment modification and repair, and inservice inspection of welds in power plants.

Simply stated, the method consists of (1) inducing a magnetic field in the article to be examined, and (2) applying magnetic particles to the surface of the article. Material defects or discontinuities affect the induced magnetic field, and corresponding patterns are formed by the magnetic particles on the surface indicative of the discontinuities which exist.

This module explains the principles of magnets and magnetic fields and how they are applied in magnetic particle testing, describes the theory and methods of magnetizing test specimens, describes the test equipment used, discusses the principles and reasons for demagnetization, and describes the applicability, advantages and disadvantages of specific test methods.

The operation of test equipment, descriptions of the types of discontinuities detected, and the recognition and interpretation of test indications will be covered in Module 32-4.

MODULE PREREQUISITES

The student shall have completed all previous modules of Course 32.

OBJECTIVES

Upon completion of this module, the student/trainee can;

1. Answer correctly applicable questions on topics covered in this module as selected from the Level II SNT-TC-1A certification written test. Note: the topics and information needed to prepare the student/trainee for the SNT-TC-1A test which are not covered in this module, are covered in Module 32-4.
2. Answer correctly with a score of 80% or better a set of written exercises covering the following topics:
   (a) principles of magnets and magnetic fields.
   (b) magnetization of test specimens
   (c) principles and methods of demagnetization
   (d) application of inspection media
   (e) permeability and retentivity of materials
   (f) characteristics of discontinuities
   (g) characteristics of test equipment: applicability, advantages, & disadvantages with respect to typical test specimens.
3. Examine actual or illustrated test specimens and specify appropriate methods of magnetization, inspection media application, and methods of demagnetization.

4. Examine illustrations of test equipment, such as power supplies, prods, coils, head stocks, yokes, etc., and identify key parts and controls, and explain the operation and/or use of each.
5. Describe the basic methods of magnetization and explain the advantages and disadvantages of each.
6. Describe the applicability, advantages and disadvantages of using the following devices for magnetizing each item given on a list of typical test specimens: prods, coils, yokes, permanent magnets, head stock contacts, and head stock central conductors.

SUBJECT MATTER

Principles of Magnets and Magnetic Field

A magnet is a body which has the property of attracting iron and producing a magnetic force field external to itself. This phenomenon occurs in an object when part or all of its molecules have their North and South poles oriented. When the molecules are oriented or aligned in this manner, the object, or magnet, has two distinct and opposite poles which are attracted by the earth's poles. Magnets have the property that "like poles repel" and "opposite poles attract". This ability to attract or repel is illustrated in Figure 32-3-1:

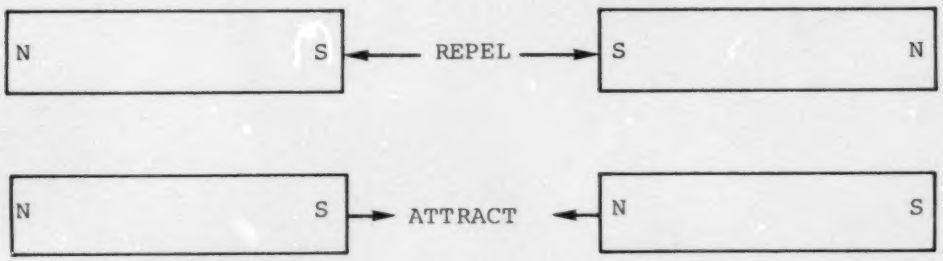


Figure 32-3-1 Magnetic Attraction/Repulsion

Since there is generally a uniform alignment of the molecules in a magnet, when a magnet is divided or broken, the resulting parts will be individual magnets with distinct North and South poles, as illustrated in Figure 32-3-2:

Figure 32-3-2 Division of a Magnet

The force field surrounding a magnet is not uniform, but is concentrated at the poles. If a sheet of paper is placed on a bar magnet, and iron filings or particles are

sprinkled over the paper, the particles will be attracted and aligned by the magnetic lines of force as illustrated in Figure 32-3-3. The figure shows that the lines don't cross, and are densely arranged at the poles.

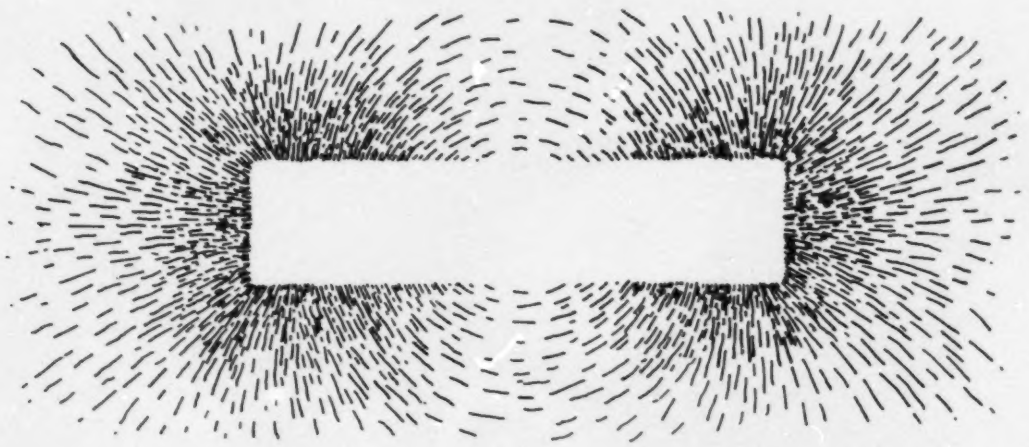


Figure 32-3-3 Magnetic Field Surrounding Bar Magnet

If the bar magnet is broken in half (thereby creating two magnets), and the paper and filings demonstration is repeated, the magnetic lines of force will be displayed as shown in Figure 32-3-4, with an accumulation of filings at the junction of the two magnetic parts.

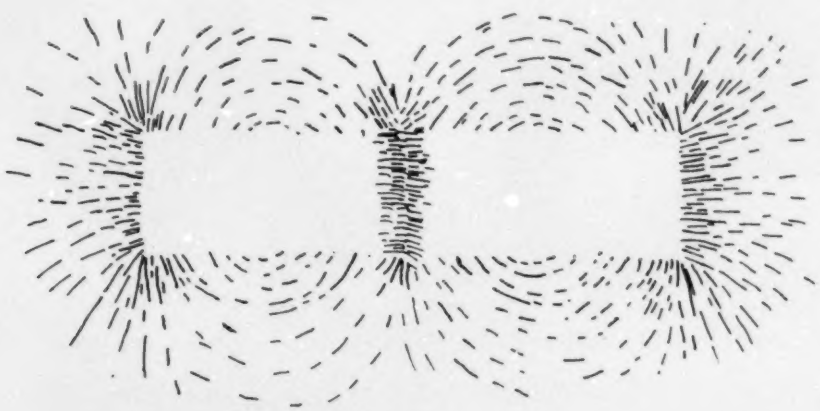


Figure 32-3-4 Magnetic Field Surrounding Broken Bar Magnet

The phenomenon illustrated in Figure 32-3-4 provides a basis for the magnetic particle inspection method: when a magnetic field or flux in an object is interrupted by a break or discontinuity in the material, a new flux pattern will be created, new poles will be formed, and iron particles will be attracted to that location.

When more than two poles exist simultaneously within a magnetized object, the poles are known as consequent poles.

Magnetic field characteristics are exhibited by both permanent and temporary magnets. Permanent magnets are those which retain their magnetism more or less permanently, and temporary magnets are those which retain their magnetism only as long as a magnetizing force is applied.

A magnetic field also exists around a conductor carrying an electric current. If the conductor has a uniform shape, the density of the flux is uniform at any point along the conductor, and decreases as the distance from the conductor increases. The circular magnetic field forms a closed loop pattern of lines of force around the conductor as shown in Figure 32-3-5. The direction of such an electrically induced magnetic field may be determined by using the "right hand rule", that is, if the right hand grasps the conductor with the thumb pointing in the direction of the current flow, the fingers will point in the direction of lines of force.

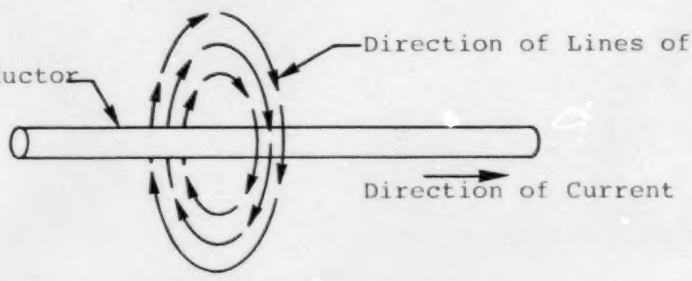


Figure 32-3-5 Circular Magnetic Field

If a current-carrying conductor is formed in a loop, as shown in Figure 32-3-6, the lines of force inside the loop will all point in the same direction, and a longitudinal magnetic field will be created.

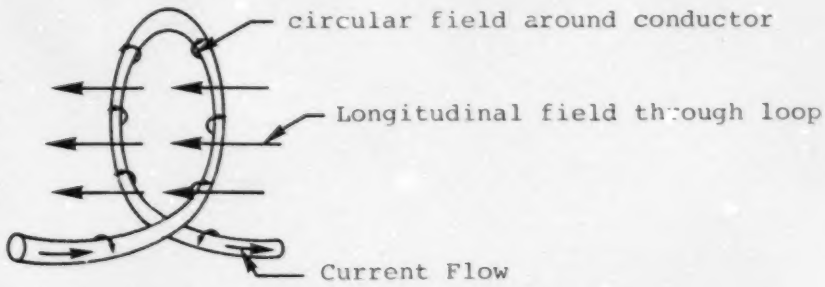


Figure 32-3-6 Longitudinal Magnetic Field

As more loops are added to the coil, the magnetic field strength increases in proportion to the number of loops.

The magnetizing forces and resulting magnetic fields for any specific material can be represented graphically by plotting magnetizing force vs. flux density. The resulting diagram is known as the hysteresis curve for that material, as illustrated in Figure 32-3-7.

In this illustration, a piece of unmagnetized steel is exposed to a magnetizing force (H+) in incremental steps beginning at point 0, and the induced flux density (magnetic field) increases until it reaches point 1, beyond which any further increase in the magnetizing force does not increase the flux density. At this point, the material is said to be magnetically saturated. This plot, from 0 to 1, is defined as the virgin curve of the material.

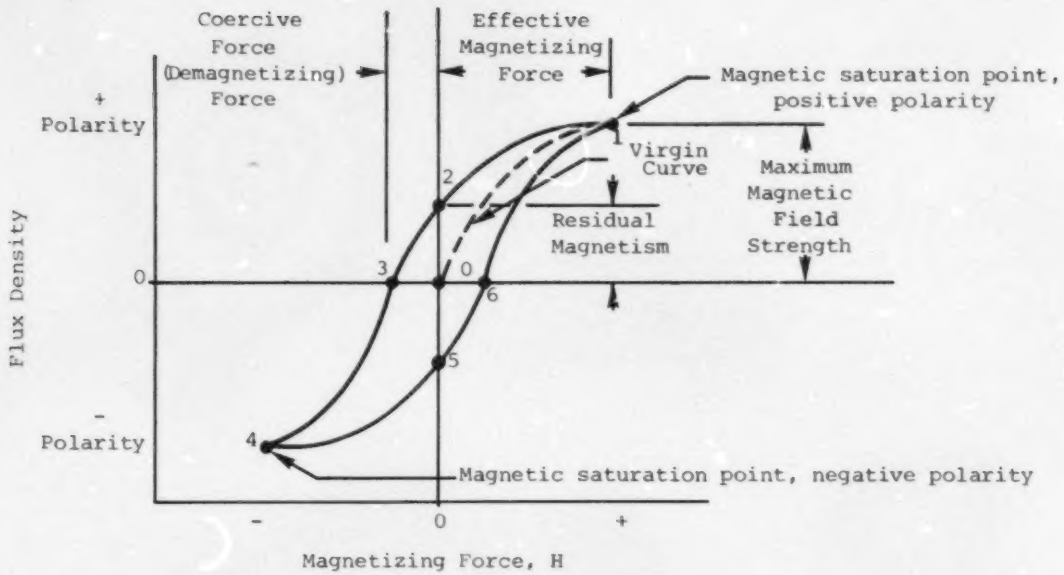


Figure 32-3-7 Hysteresis Curve

When the magnetizing force is reduced to zero, the flux density drops only to point 2. The remaining flux density, represented as 0-2, is residual magnetism. As a negative or reversed magnetizing force is applied, the flux density decreases to zero; this force, shown as 0-3, is the coercive force in the material. When the reversed magnetizing force is further increased, magnetic saturation is again achieved at point 4. As the magnetizing force diminishes to zero, the flux density decreases to point 5, again leaving a residual field. The magnetizing force is then applied in the positive direction to reduce the flux density back to zero, thereby completing the cycle. The area within the curve then represents the hysteresis characteristics, or the lag between the magnetizing force and the flux density throughout the magnetization/demagnetization cycle, for that particular material.

Different ferromagnetic materials have different magnetic properties, and consequently, have different hysteresis curve characteristics. If a characteristic curve exhibits a wide loop, the material will have high reluctance and be difficult to magnetize, but also will retain a high residual field. A curve with a narrow loop, however, represents material that magnetizes easily, but retains a weak residual field. Curves with these characteristics are illustrated in Figure 32-3-8.

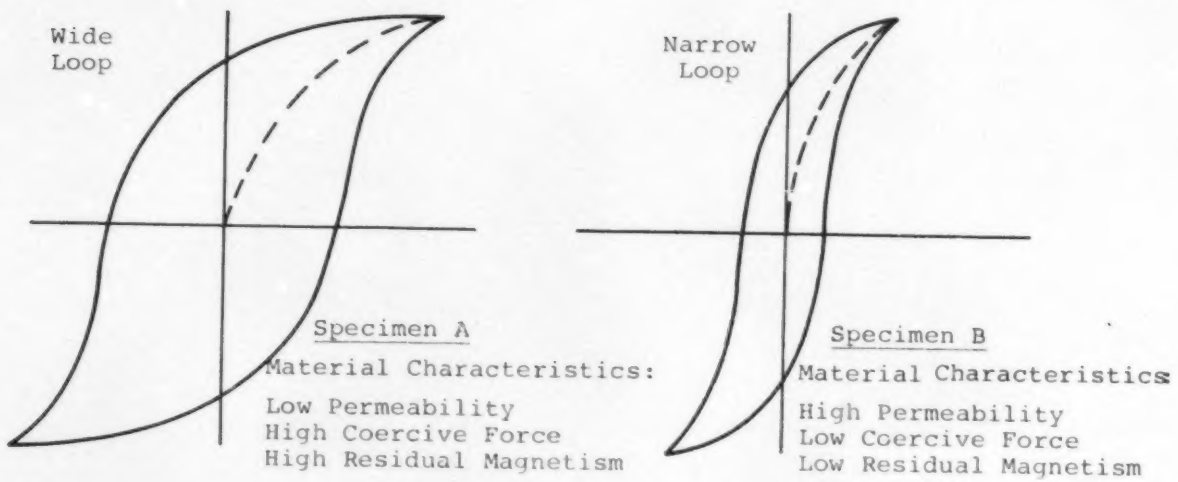


Figure 32-3-8 Comparison of Materials and their Respective Hysteresis Curves

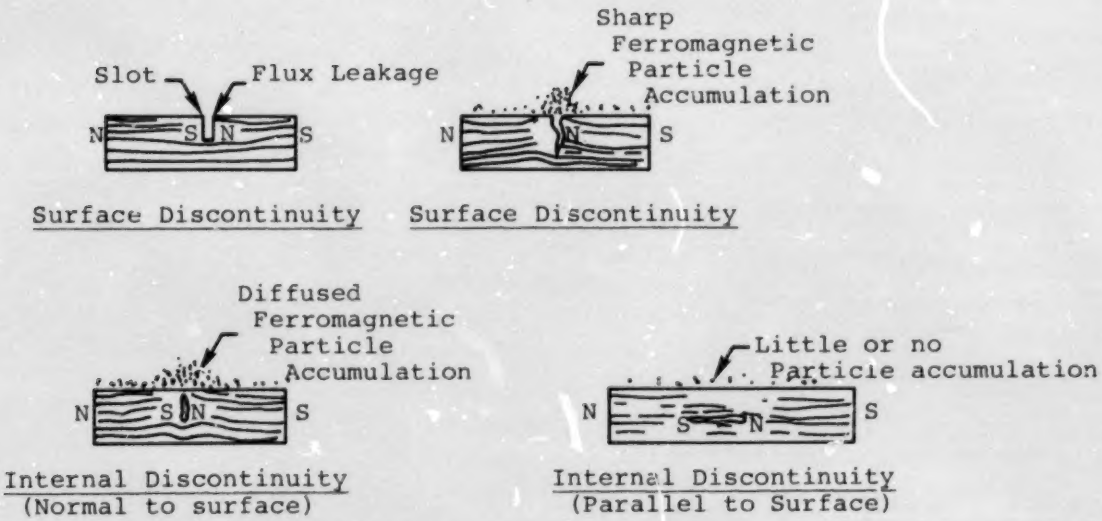


Figure 32-3-9 Material Discontinuities and Orientation

Figure 32-3-9 illustrates that discontinuities that extend to the surface produce sharp, well defined indications, and shallow sub-surface discontinuities produce diffused indications consistent with the strength of the leakage field. When a discontinuity occurs at a greater depth, or its long axis is parallel to the surface, the leakage field is either very weak or is nonexistent on the surface, and the discontinuity cannot be detected with this technique.

Characteristics of Magnetizing Currents

The types of magnetizing currents best suited for, and normally used in magnetic particle testing, are alternating current and half-wave rectified current. Direct current is used to some extent with solenoids and yokes, and has excellent penetrating characteristics. However, it is not generally suitable for circular magnetization usage (where the current strength must be varied with the specimen size) since it cannot be stepped down in voltage with transformers.

Alternating Current

Alternating current has the characteristic that it reverses direction in a cyclical pattern, normally at a frequency of 60 hZ (cycles per second). Its wave form is shown in Figure 32-3-10.

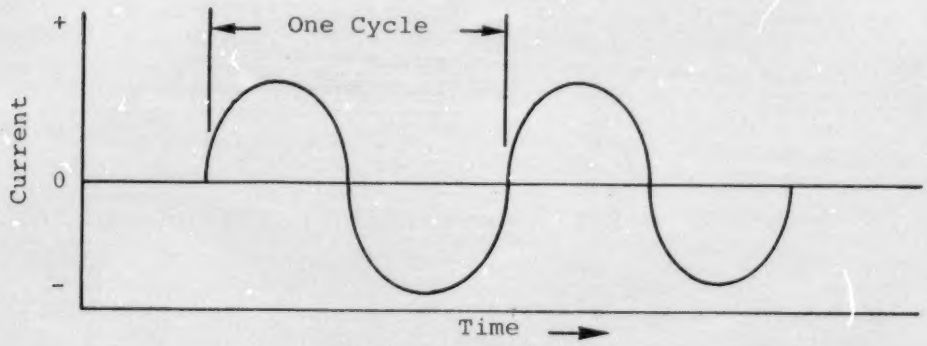


Figure 32-3-10 Wave Form, Single Phase Alternating Current

Beginning at a zero value, the current flow increases to a maximum positive value, decreases to zero, reverses direction, increases to a maximum negative value, and decreases again to zero, completing one cycle.

Alternating current (AC) has little penetrating ability, but creates a maximum magnetic flux at the surface of the specimen, a phenomenon known as the "skin effect". Consequently, AC is most useful for locating surface discontinuities.

AC can easily be stepped up or down with transformers and its characteristic of magnetic field reversal promotes the mobility of magnetic particles and their collection at leakage fields.

Half-wave Rectified Current

Alternating current is passed through a rectifier and converted to half-wave rectified, also called half-wave direct current (HWDC). The rectifier allows the current to flow in one direction only, as shown in Figure 32-3-11, preventing the current and subsequent magnetic field reversal.

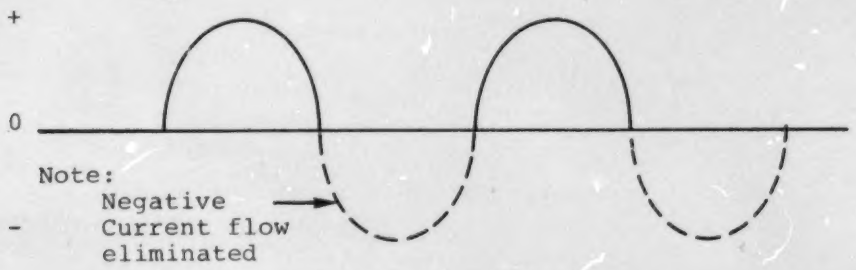


Figure 32-3-11 Wave Form, Half-Wave Rectified (Direct) Current

The resulting current is pulsating DC, with high penetrating ability and influence on magnetic particle mobility.

Since the hwdc is produced from AC, the voltage can be varied easily, and outputs for both types can be provided on the same power supply. Hwdc combines the pulsating advantage of AC for particle mobility with the penetrating advantage of DC, and is best suited for locating sub-surface discontinuities.

Methods of Magnetization

The following paragraphs describe the most commonly used methods of magnetizing specimens for magnetic particle inspection:

Coil or Solenoid Magnetization:

A specimen whose length is between 2 and 15 times its diameter and less than 18 inches in length may be magnetized with a longitudinal field by placing it in a current carrying coil as illustrated in Figure 32-3-12.

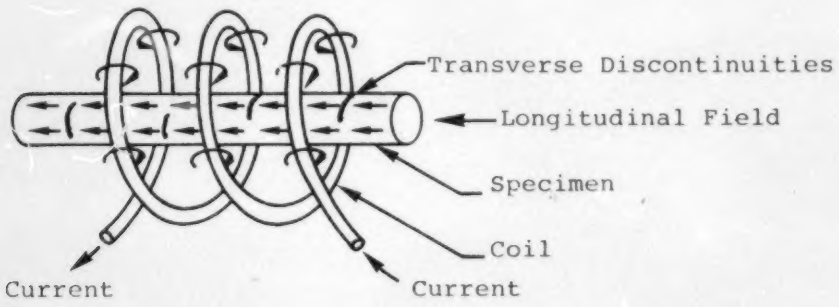


Figure 32-3-12 Coil (or Solenoid) Magnetization - Longitudinal Field

When using this technique, the specimen should be held against the inside wall of the coil and not positioned in the center of the coil.

The strength of the induced magnetic field is approximately proportional to the number of turns in the coil. For example, double the number of turns and the magnetic flux will be doubled. The length of the induced field is limited, however, and several "shots" may be required for a long specimen to adequately magnetize the entire part.

This method of magnetization is most effective in locating transverse discontinuities or defects which cross the induced longitudinal lines of flux, as illustrated in Figure 32-3-12.

Yoke Magnetization:

The yoke is a temporary soft iron horseshoe magnet which is magnetized by passing a current through its horizontally wound coil, as shown in Figure 32-3-13.

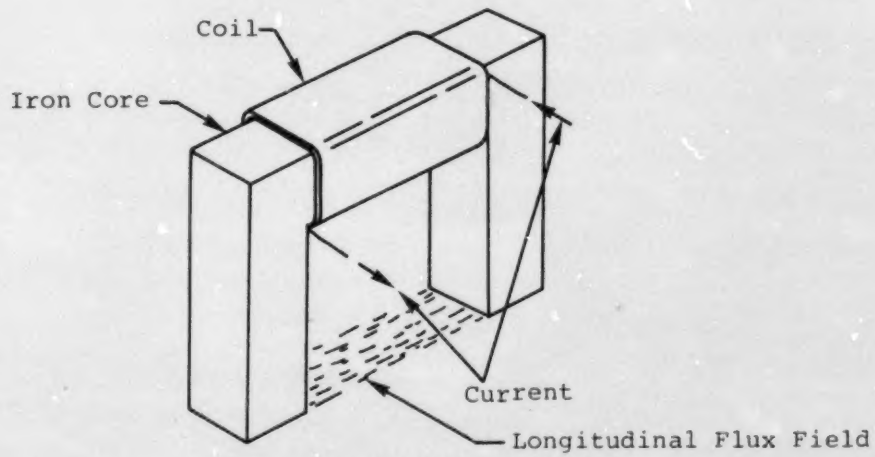


Figure 32-3-13 Yoke Magnetization

When the energized yoke is placed in contact with the surface of the specimen, a local longitudinal magnetic field is induced.

The force field produced by the yoke is constant and cannot be varied. The yoke is used most effectively on highly permeable (easily magnetized) materials, and locates discontinuities transverse to the induced field.

In using the yoke, the usual practice is to magnetize the specimen in one direction and inspect for defects, then magnetize the specimen a second time in the same area but in a direction rotated 90° from the first direction, and reinspect.

By using this technique, all discontinuities will be exposed more or less transversely to the magnetic flux lines, and will be detected.

Direct Induction Magnetization

A circular field may be induced directly in a specimen by passing a current through the article, as shown in Figure 32-3-14. Magnetization produced in this manner with stationary equipment is called a "head shot".

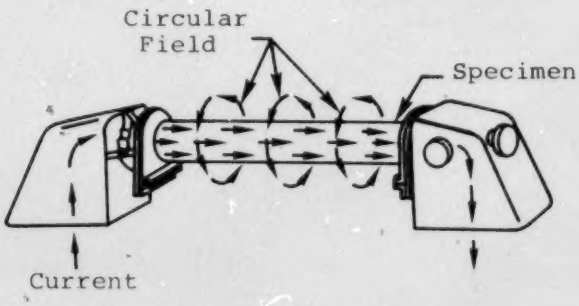


Figure 32-3-14 Direct Induction ("Head Shot") Magnetization

The magnetic field strengths resulting from the current flow vary from zero in the center of a solid specimen or the inside surface of a hollow specimen, to a maximum value at the surface.

Since this technique induces a circular magnetic field in the specimen, it is most useful for locating discontinuities oriented longitudinally in the specimen. To avoid the possibility of overlooking transversely oriented defects, such parts are usually inspected a second time with a longitudinal magnetic field.

Direct Induction Magnetization with Prods

A distorted circular field may be induced in a specimen by passing a current through the specimen by the use of portable (hand held) prods, as shown in Figure 32-3-15.

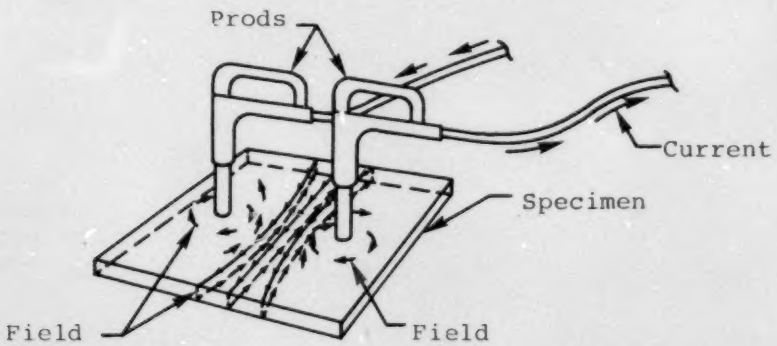


Figure 32-3-15 Direct Induction ("Prod") Magnetization

This technique is used widely for inspecting welds and many other applications where the size, shape or location of an article precludes the use of a head shot or a central conductor technique.

Permanent Magnet Yoke Magnetization

Adjustable permanent magnet yokes as shown in Figure 32-3-16, may be used to induce longitudinal magnetic fields in highly permeable materials. Permanent magnet yokes do not produce magnetic fields as strong as those produced by electromagnetic yokes, so their use must be limited to easily magnetized materials, and for investigating surface discontinuities only.

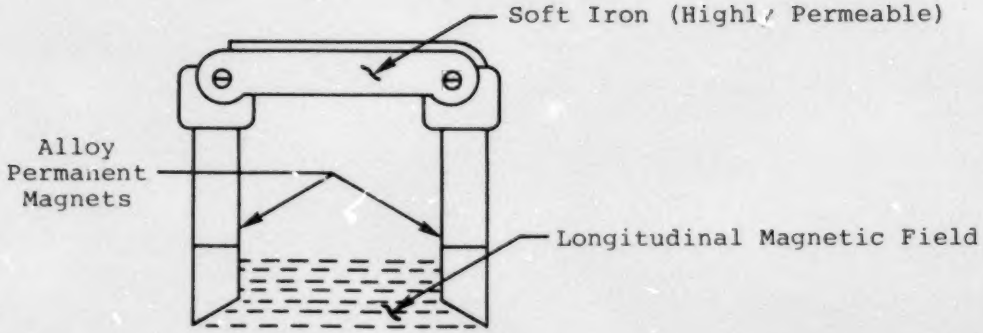


Figure 32-3-16 Permanent Magnet Yoke Magnetization

Central Conductor Magnetization

A central conductor may be used to induce a circular field in a hollow specimen, as shown in Figure 32-3-17.

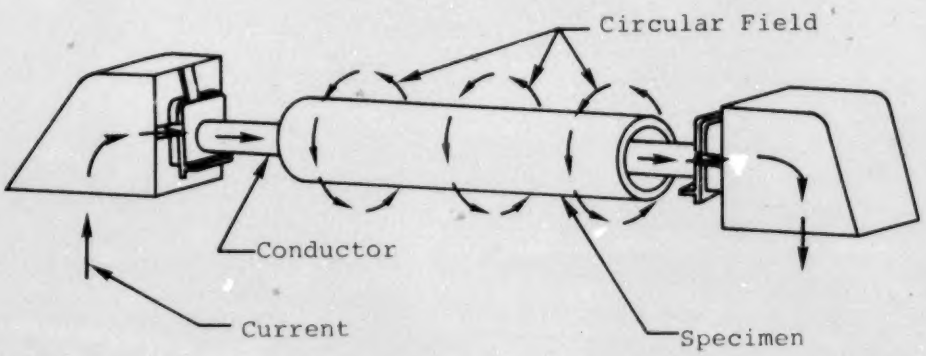


Figure 32-3-17 Central Conductor Magnetization

Cable Magnetization

Large specimens may be magnetized effectively with the use of cables, as shown in Figure 32-3-18.

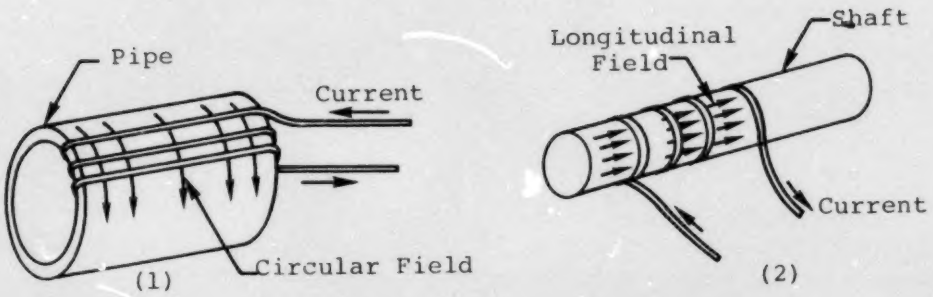


Figure 32-3-18 Cable Magnetization, Large Specimens

In specimens where the current-carrying cable can be coiled through the part as in (1), a circular field can be induced.

In solid specimens such as in (2), the cable can only be wrapped around the part, and a longitudinal field results.

Portable Power Units

Compact, portable power units of the type shown in Figure 32-3-20, are used to provide magnetizing current for many of the applications mentioned for the mobile units, with the limitation of providing only 500 - 1000 amperes. The units can be moved to otherwise inaccessible areas, however, where larger equipment cannot be used. Portable units usually operate on 110/220 volt AC, and supply AC or halfwave DC current.

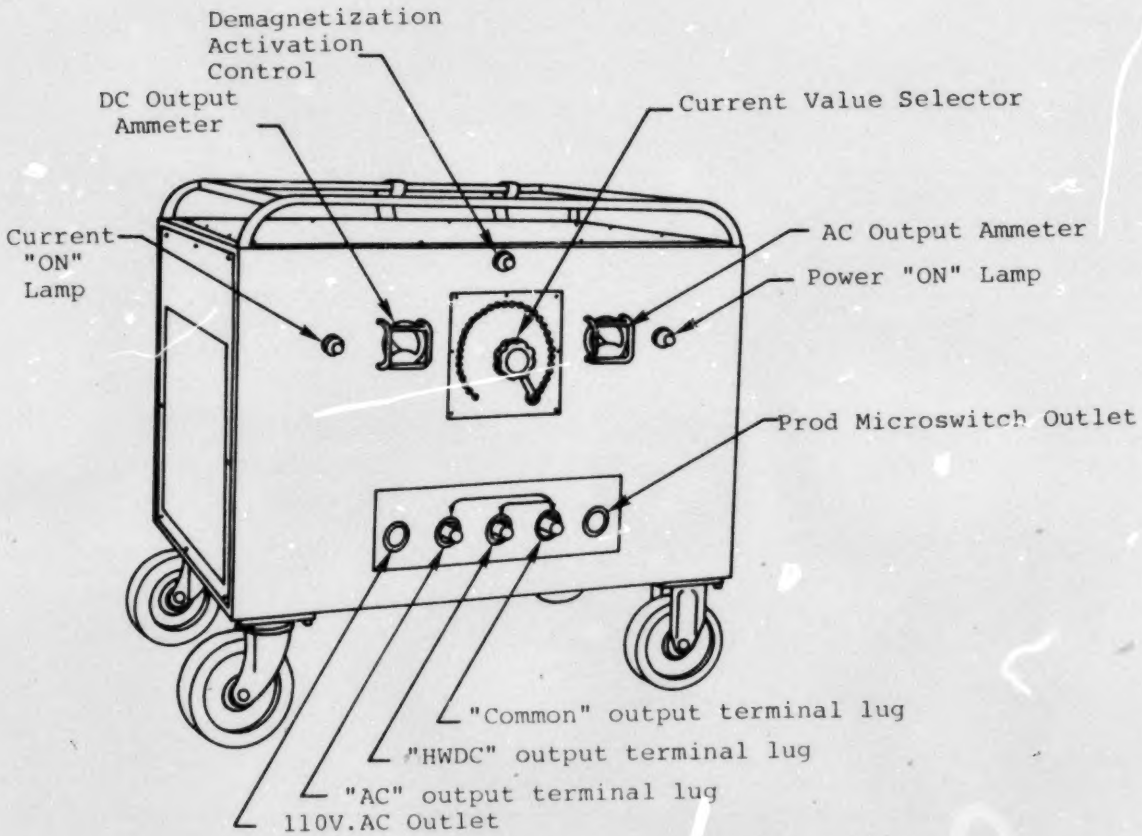


Figure 32-3-19 Mobile Magnetic Particle Power Unit

Accessory Equipment

Prods

"Prods" are hand held electrodes connected to the power unit with heavy, flexible cables, and are used to introduce a magnetizing current into the component under inspection.

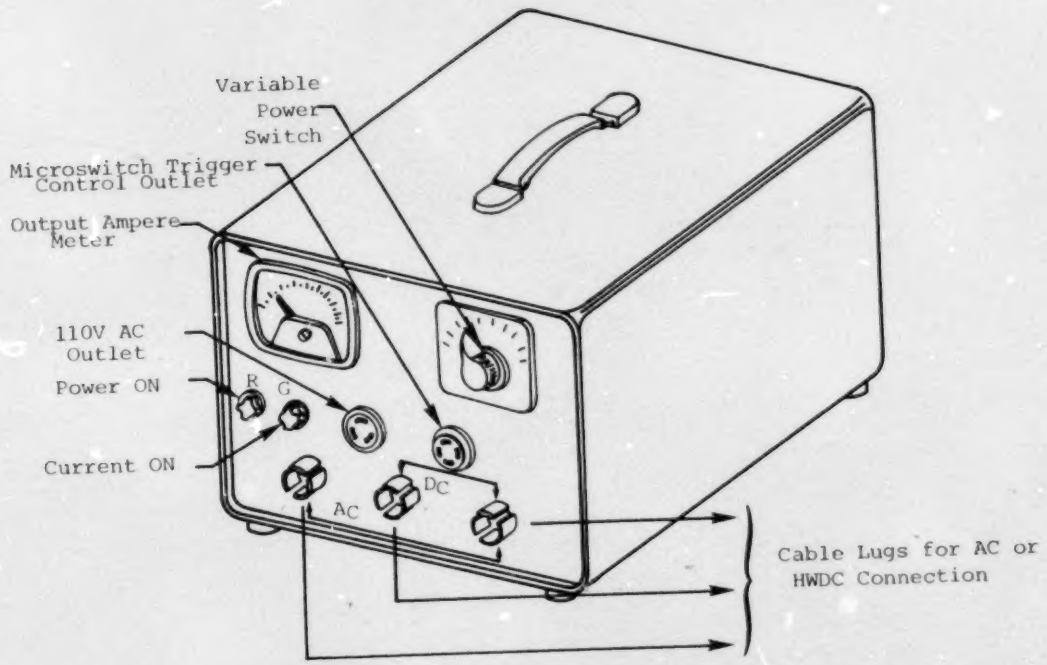
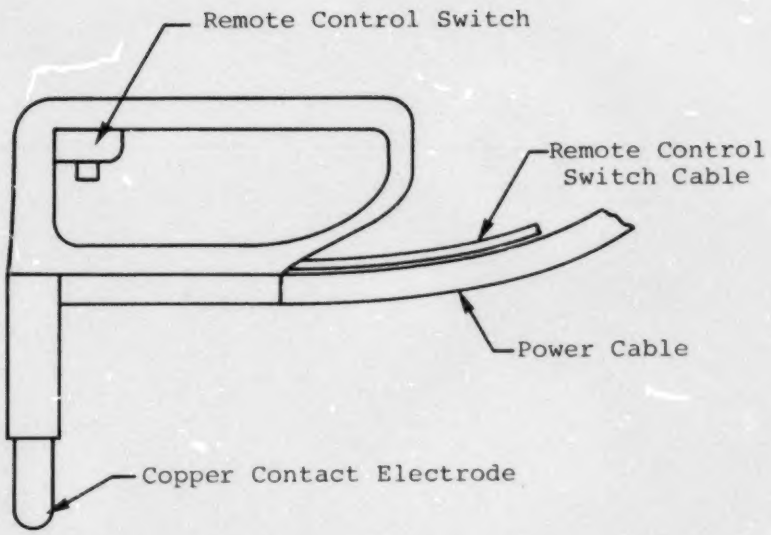


Figure 32-3-20 Portable Magnetic Particle Power Unit

Prods may be of two different types, as illustrated in Figure 32-3-21.

1. Individual prods for each cable, with a remote control switch built into one of the prod handles. The switch is connected to the power unit microswitch outlet with a separate cable, and is used to activate a relay in the power unit which turns on the magnetizing current after the prods have been properly positioned on the test specimen. Or,
2. Dual-prod assembly, with fixed prod spacing, and remote control switch installed in the handle.



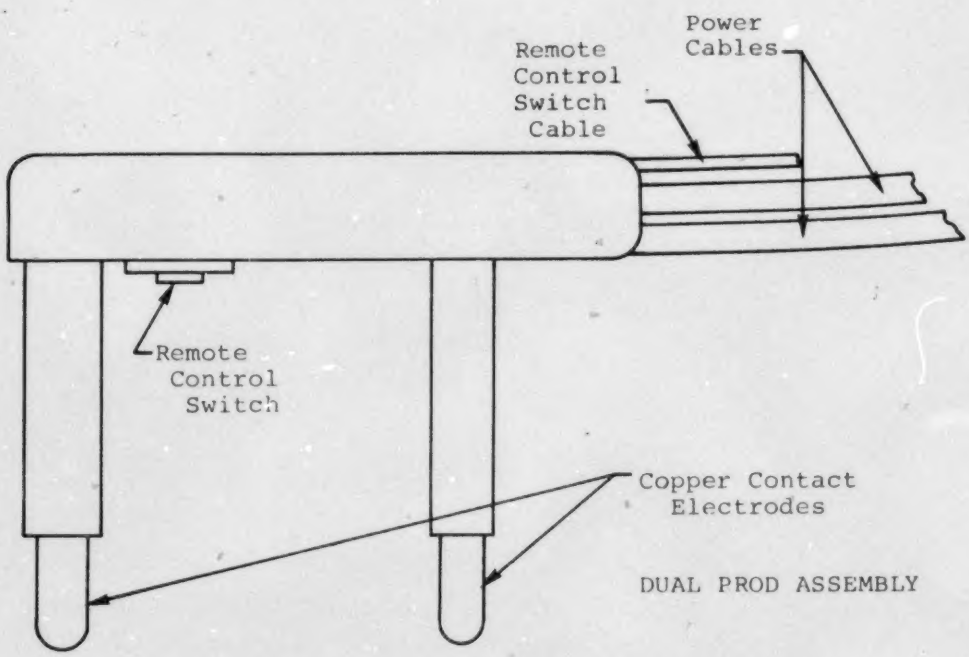


Figure 32-3-21 Accessory Prods

Magnetizing/Demagnetizing Coils

"Coil" assemblies which operate with either AC or HWDC current may be used for magnetizing and demagnetizing shafts, axles, spindles, bolts, or other light parts. A typical coil, as shown in Figure 32-3-22, has a foot operated switch for continuous control by the technician.

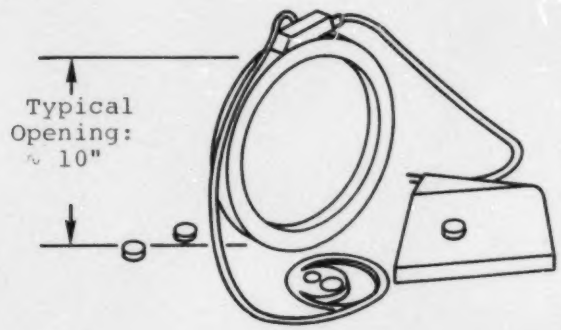


Figure 32-3-22 Magnetizing/Demagnetizing Coil

Cables

"Cables" used for carrying magnetizing currents in magnetic particle testing are usually made-up from heavy gauge rubber or neoprene covered welding cable. Such cables are constructed with soft annealed copper stranded conductors to provide maximum flexibility and minimum electrical resistance.

Magnetizing Yokes

"Yokes" are hand-held, "U" shaped magnetizing devices equipped with either a 110 volt ac electromagnet, or with alloy permanent magnets for generating a magnetic flux field. The openings between legs of typical yokes are approximately 5-6 inches.

Yokes produce flux fields of sufficient strength to locate surface discontinuities in welds, castings, and a variety of structures and parts.

Several types of yokes are illustrated in Figure 32-3-23.

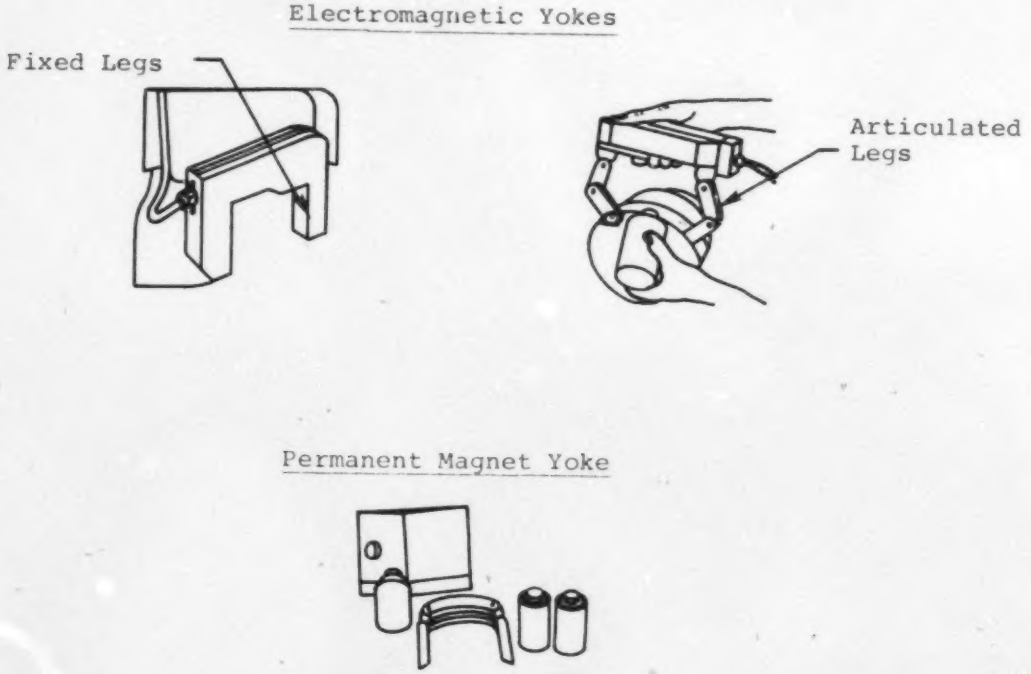


Figure 32-3-23 Magnetizing Yokes

Inspection Mediums

The selection of a suitable inspection medium is basic to the success of any magnetic particle test. The mediums used are non-toxic, metallic, or metallic oxide particles, free of contaminants, with four specific properties: magnetic, geometric, mobile and visible. Application

of the mediums may be accomplished with the dry method or the wet method, depending on the characteristics of the test specimen and the type of discontinuities to be detected.

Properties of inspection mediums:

1. Magnetic

   The particles must exhibit maximum response in a magnetic leakage field, and thus must possess high permeability (easily magnetized). Low retentivity is also desirable for ease in removal of the particles from the specimen following the test.

2. Geometric

   The shapes and sizes of particles have a significant effect on particle mobility and attraction by leakage field. Spherical shaped particles have a high degree of mobility but low attractive power, while long slender particles have a high degree of mobility but low attractive power resulting from strong, induced magnetic fields. Small particles are required to indicate small, tight discontinuities, and to respond to weak leakage fields; larger sizes are more suitable for indicating wider or larger discontinuities.

3. Mobility

   When particles are applied to the surface of a magnetic specimen, they must be mobile or free to form patterns or indications at locations of leakage fields. This mobility is influenced by particle shape and size, field strength, specimen surface condition, and method of application.

4. Visibility

   Particles must be readily visible, or contrast sharply with the background, when they collect

at a leakage field location and indicate a discontinuity. Powders used in the dry application method are usually coated with a red, black or gray color, and should be selected to provide maximum contrast on the particular specimen material. Particles used in the wet method may be red or black oxides, or coated with a dye which fluoresces brightly under ultraviolet or black light.

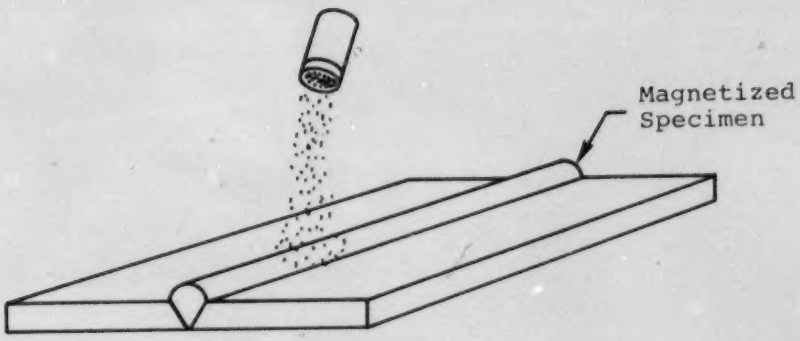
Application of Inspection Mediums:

1. Dry Method

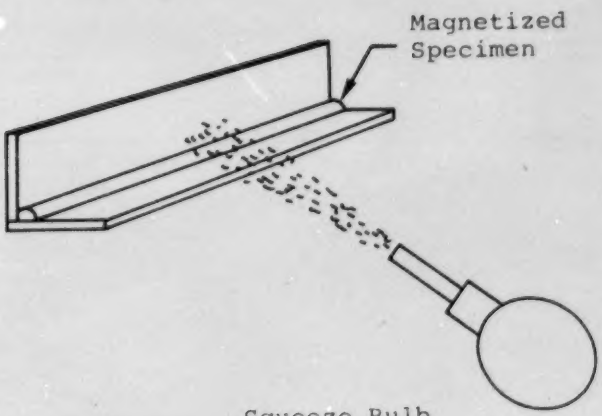
   Magnetic particles are normally applied to the specimen by dusting lightly from shaker cans or blowing from squeeze bulbs. The particles are floated down to the surface, permitting the leakage fields at discontinuities to attract and hold some of the particles as they move by. Following the application of the powder, the excess is removed with a gentle air stream. Methods of applying the dry powder are illustrated in Figure 32-3-24.

2. Wet Method

   Finely divided particles or iron oxide are suspended in a low viscosity petroleum distillate or water, and applied to the specimen either by spraying, flowing or brushing onto the surface, or by immersion. The particles used in the suspension may be colored red or black, or may be the fluorescent type which requires that the specimen be inspected under black light.



Shaker Can



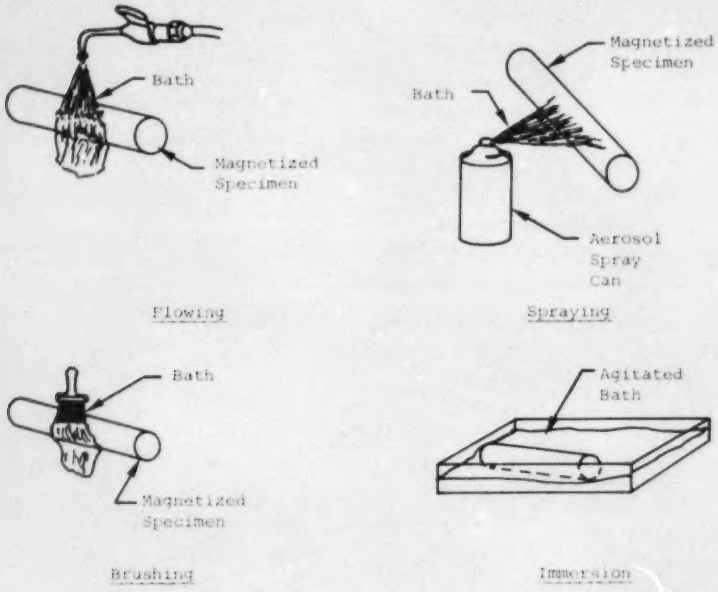
Squeeze Bulb

Figure 32-3-24 Particle Application - Dry Method

This method provides maximum particle mobility, and, due to the extremely small particle size, is well suited for detecting very small discontinuities extending to the surface of the specimen.

Test sensitivity is dependent on particle concentration in the bath, however, so proper preparation and maintenance of the bath is essential. The suspension should be agitated or circulated during use, and protected from contaminants.

Methods of applying the suspension are illustrated in Figure 32-3-25.



NOTE: Magnetic particles are suspended in the bath, and applied to the surfaces of test speciments as illustrated.

Figure 32-3-25 Particle Application - Wet Method

Stationary Equipment - Wet Method

Most magnetic particle inspection by the wet method is done with stationary type equipment such as that shown

in Figure 32-3-26. Units of this type are complete testing systems for processing and inspecting parts. Typical units feature variable AC/DC power supplies, suspension reservoir tanks, suspension collection or drain tray, suspension circulating pumps, ultraviolet inspection lights, magnetizing and demagnetizing coils, and head stock/clamping assemblies for holding test specimens.

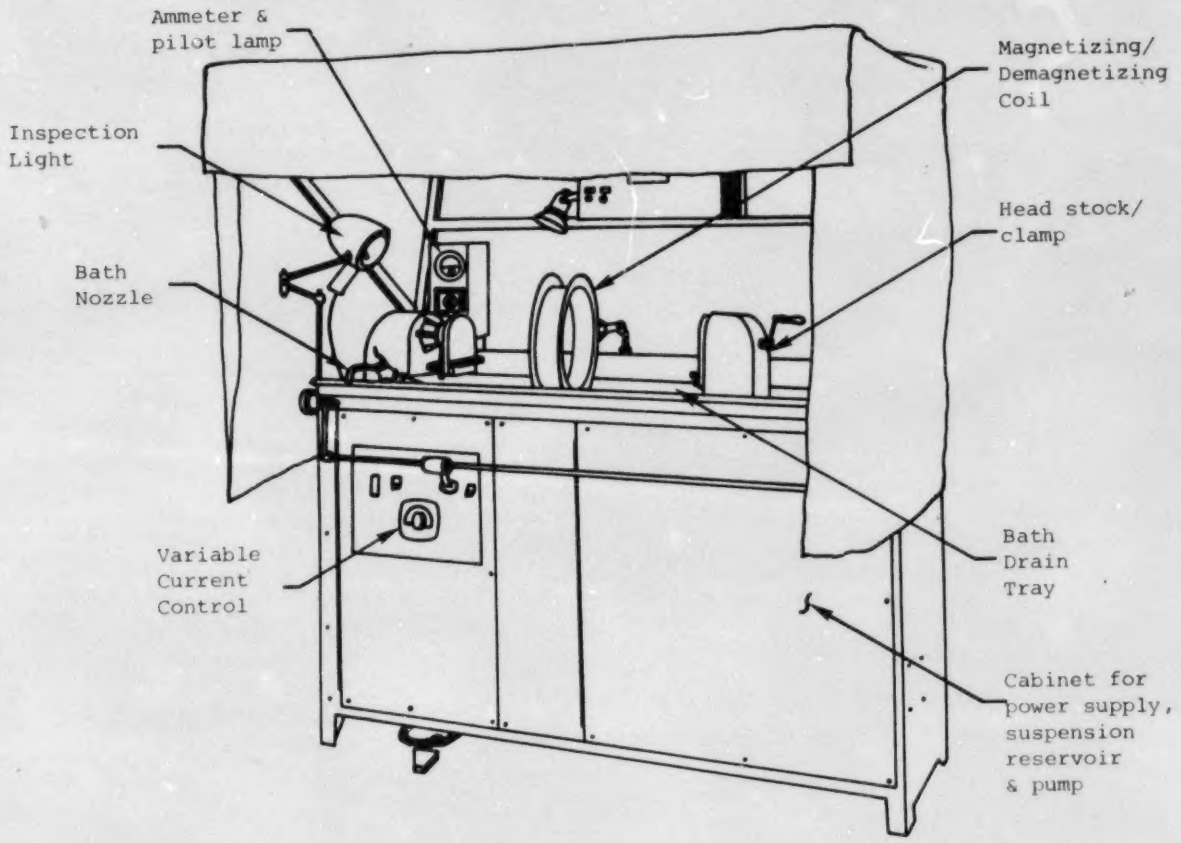


Figure 32-3-26 Stationary Equipment - Magnetic Particle Testing, Wet Method

Ultraviolet Inspection Lights

When magnetic particle testing is done with the wet method and fluorescent particles, examination is performed under high intensity near ultraviolet (black) lights, provided with suitable clean filters which eliminate the short-wave length burning rays and pass most of the visible light. For general use, the measured light intensity at the surface of the specimen inspected is recommended to be 90 foot-candles.

A typical inspection light of this type is shown in Figure 32-3-27.

Figure 32-3-27 Ultraviolet (black) Inspection Light

Principles of Demagnetization

Some residual magnetism is usually retained by ferrous materials after being removed from the magnetizing force. The strength of the residual field is dependent on the permeability and retentivity of the material, and the strength and direction of the magnetizing force. The opposite magnetic force that is required to neutralize a residual field in ferromagnetic material, and return the material to its original nonmagnetic condition is called the coercive force.

Demagnetization is required when (a) the residual field may interfere with subsequent operations such as welding or machining, (b) the specimen is a moving part of an assembly and accumulated ferrous particles and chips could cause wear, or (c) the residual field could affect nearby instruments or controls.

It is extremely difficult to attain complete demagnetization, so an acceptable level is usually determined and defined, and the residual field reduced to that value.

Demagnetization of parts may be accomplished by subjecting the magnetized part to a continuously reversing magnetic field (Coercive force) which gradually decreases in strength. The residual field in the article can be quickly reduced to an acceptable level with this technique.

Demagnetization may be performed with either alternating current or direct current:

Alternating Current Demagnetization

The easiest method of demagnetization is to pass the magnetized part through a coil which is energized with alternating current. The induced field in the part is continuously reversed as the current reverses in the coil. As the part is withdrawn and removed further from the coil and its magnetic influence, the induced field in the part becomes weaker and weaker.

Direct Current Demagnetization

In order to demagnetize with direct current, the magnetizing equipment must be equipped with appropriate controls for fine, incremental current reduction and current reversal. With such controls demagnetization can be performed more effectively than with alternating current.

The procedure to be used is to place the part in a coil and adjust the current to a value equal to or greater than that used to magnetize the part; then stop the current flow, readjust the current to a lower value, reverse the direction of flow, and give the part a "shot" of current at this setting. This procedure of current reversal and reduction is continued until the lowest adjustable value is reached, usually in 25 or more small, incremental changes.

Demagnetization may not be required for specimens such as large weldments or vessels where residual fields have no detrimental effect, or for specimens to be heat treated, for when ferromagnetic materials are heat treated, the curie point is usually surpassed (e.g., the temperature at which magnetic materials lose their residual magnetism).

Applicability of Magnetic Particle Test Methods

The two basic magnetic particle test methods, the dry method and the wet method, differ in the test medium particle size, and the relative particle mobility characteristics.

The dry method is particularly well suited for inspecting large parts such as casting, forgings and weldments with local circular magnetism induced directly with prods. The dry powder technique is more sensitive in detecting near surface discontinuities than the wet method, but is less sensitive in detecting fine, surface discontinuities. The dry method is most convenient for use in field inspection

work and for inspecting large areas due to the simplicity in equipment requirements (a means of inducing a magnetic field, and a means of dusting on powder).

Typical discontinuities which may be detected with the dry method are:

- surface flakes in forgings
- fatigue cracks in parts in service
- shrinkage cracks in castings and in welds
- tears in castings
- porosity or sub-surface sand in castings
- unfused chaplets in castings
- sub-surface cracks and inclusions in welds
- lack of fusion in welds
- plate laminations

The inspection medium used in the wet method consists of extremely small particles, on the order of a few microns in size, suspended in a low viscosity liquid for maximum particle mobility. This medium is very sensitive to weak leakage fields, and is well suited to the detection of very fine discontinuities extending to the surface, such as grinding cracks and fatigue cracks.

The wet method is usually used for inspecting smaller parts, such as aircraft, automotive, or machine parts, where stationary equipment is available. In most cases, the entire part can be magnetized, and the indicating medium flowed easily over all surfaces; or the part is immersed in the indicating suspension bath. With the use of the stationary equipment, the excess suspension material is collected in a reservoir and reused, with very little material loss. Contrasting color particles may be used in the bath, or fluorescent particles may be used which require inspection under black light.

Many items are inspected automatically with fully-automated production line equipment, using wet method magnetic particle defect detection and laser scanning techniques. Such systems are used in the manufacture of steel mill products, and automotive, aviation and railroad products.

In some cases, large precision machined parts, such as shafts, are inspected with the wet method, usually with fluorescent type particles, in examining for stress or fatigue cracks.

Advantages and Disadvantages of Magnetic Particle Test Methods

In general, the advantages of magnetic particle inspection are:

- the method can be used on any specimen made of ferromagnetic material
- the method can be utilized almost anywhere with portable equipment
- the method is a positive means of detecting surface or near-surface defects
- personnel are easily trained to operate equipment & interpret results
- test equipment and materials are relatively inexpensive

Some of the limitations and disadvantages of the test method are:

- method is applicable only to magnetic materials
- pinpoint inclusions are difficult to locate
- hairline cracks are hard to locate, and may be overlooked if they happen to line-up with the magnetic lines of force

- false indications of defects can result from:
  - abrupt changes in permeability of the specimen material
  - junctions of different metals (different permeability)
  - cold working of some metals (change in permeability)
- subsurface defects in welds such as slag inclusion, lack of fusion, lack of penetration, porosity and internal shrinkage cracks cannot be detected much beyond 0.25 inches below the surface
- laminations in plate cannot be detected unless the leakage field penetrates to the surface (which normally happens only at the plate edge)
- false indications can occur from careless handling of parts, or dragging one part across another after magnetizations. Blurred line indications are produced on the surfaces of the parts, and are known as "magnetic writing"
- use of prods in applying magnetizing current can produce arcing and burns detrimental to the specimen, leading to ultimate failure in service.

EXERCISES

1. Indicate whether the following statements are true or false:

___ a. Uniform alignment of molecules usually occurs in magnetized materials.

___ b. A magnetic field in a magnetic material is also known as magnetic flux.

___ c. The "right hand rule" is a simple procedure for determining magnetic field strength.

___ d. The magnetic field produced by a coil decreases in strength as additional loops are added to the coil.

___ e. The magnetic field in a bar magnet will be destroyed when the magnet is broken in half.

2. Complete the following statements by filling in the blanks:

a. The magnetic force field surrounding a bar magnet is concentrated at the _____.

b. A property of magnets is that _____ poles repel, and _____ poles attract.

c. A _____ magnetic field always surrounds a conductor carrying an electric current.

d. A _____ magnetic field is produced within a current-carrying coil.

3. Match the correct word with the statement:

a.	Materials repelled by magnetism ___	(1)	reluctance
b.	Materials attracted by magnetism ___	(2)	coercive force
c.	Resistance to magnetizing force ___	(3)	magnetic flux
d.	Demagnetizing force ___	(4)	diamagnetic
e.	Easily magnetized material ___	(5)	residual field
f.	Maximum magnetic field strength ___	(6)	paramagnetic
g.	Lag between magnetizing force	(7)	retentivity
	and flux density ___	(8)	hysteresis
		(9)	permeable
		(10)	saturation

4. Indicate whether the following statements are true or false:

___ a. A magnetized material with low permeability usually will have high residual magnetism.

___ b. A high coercive force is required to remove a residual field from highly permeable material.

___ c. Usually the same amount of current is required to remove the residual magnetism from a specimen, that was used to initially induce the field.

___ d. A magnetic field in magnetically saturated material can be doubled by doubling the magnetizing current.

5. Complete the following statements:

a. Surface or near surface discontinuities in magnetized ferromagnetic materials produce _____ _____ which will attract magnetic particles.

b. Diffused indications are usually produced by _____ defects.

c. Internal discontinuities, either deep or lying _____ to the surface, are very difficult to detect.

d. A leakage field develops when a _____ is interrupted.

6. Complete the following statements:

a. The two types of current most used for inducing magnetic fields in test specimens are _____ and _____.

b. _____ can be easily stepped up or stepped down in voltage with transformers.

c. _____ may be used to induce a pulsating, deeply penetrating magnetic field in a test specimen.

d. Magnetizing a part by passing an electric current through the part is called _____.

e. The use of a central conductor in magnetizing a hollow test specimen produces a _____ magnetic field in the part.

f. Permanent magnet yokes are most useful for detecting _____ discontinuities.

g. The use of prods in magnetizing a test specimen produces a _____ field.

h. Electromagnetic yokes produce _____ flux fields.

i. Discontinuities in a test specimen will not be detected unless they cross _____.

j. The strong magnetic field produced on the surface of a part by the use of alternating current for direct induction is called the _____.

7. Indicate true or false for the following:

___ a. Half-wave rectified current is best suited for locating surface defects.

___ b. The pulsating characteristic of half-wave rectified current improves magnetic particle mobility.

___ c. A rectifier permits current to flow in one direction only.

___ d. Alternating current is not suitable for locating deep, sub-surface discontinuities.

___ e. Longitudinally oriented defects are best found by inducing a longitudinal field in the part.

8. Indicate true or false for the following:

___ a. Magnetic particle power units usually have variable power outputs for both alternating current and half-wave rectified current.

___ b. Prods are used for the direct induction of magnetizing current in test specimens.

___ c. Due to high electrical resistance, welding cable cannot be used for carrying magnetizing currents.

___ d. Yokes are useful for inspecting for surface defects.

___ e. Non-magnetic particles are always used as inspection mediums in magnetic particle testing.

___ f. Fluorescent magnetic particles fluoresce brightly under infra-red light.

___ g. For maximum test sensitivity in magnetic particle inspection, the inspection medium should be applied heavily, and heaped upon the test surface.

9. Complete the following statements:

a. Demagnetization is required to remove _____.

b. Demagnetization may be accomplished by heating a magnetized part to its _____.

c. The easiest method of demagnetization is to pass the part through a coil energized with _____ current.

d. The strength of a residual field is dependent on the material _____ and _____.

e. It may be necessary to use the _____ current method of demagnetization to eliminate a residual field in a large forging.

f. In demagnetizing a large, heavy part, the current must be _____ and _____ in small, incremental steps.

10. Indicate True or False for the following statements:

___ a. The dry method is best suited for detecting fine, surface discontinuities.

___ b. The dry method is usually used for inspecting large weldments.

___ c. Stationary magnetic particle inspection equipment is usually used for examining small parts with the wet method.

___ d. Aluminum aircraft parts are usually inspected with the dry powder magnetic particle method.

___ e. The wet method with fluorescent type particles provides maximum particle contrast and mobility.

MATERIALS

The subject material contained in this module may be taught without using actual test equipment, materials, and specimens, but the availability of the items listed below to the student/trainee is highly recommended:

1. Portable or mobile power supply unit, with variable outputs for HWDC and AC current.
2. Portable, electromagnetic yoke (110v. AC type)
3. Portable, permanent magnet yoke
4. Black light inspection lamp
5. Inspection media:
   - Red & black dry powders
   - *Red wet-bath suspension powder and solvent
   - *Fluorescent wet-bath suspension powder and solvent
6. Demagnetizing coil (110 v. AC type)
7. Inspection media applicators
   - Dry powder squeeze bulb
   - Wet-bath hand sprayer
8. Light meter for checking black light lamp output.
9. Test specimens with typical defects or discontinuities.

* These materials may be obtained pre-mixed and packaged in aerosal cans.

PROCEDURES

1. Tour a magnetic particle test facility. Note power unit, test media, coils, yokes, prods, and wet or dry method and discuss notes in class.
2. Witness a magnetic particle test demonstration. Note type of current, particle application and inspection and discuss notes in class.

DATA TABLE

None.

REFERENCE MATERIALS

Betz, C.E., Principles of Magnetic Particle Testing, Magnaflux Corporation, Chicago, Ill.

Libby, Hugo L., Introduction to Electromagnetic Nondestructive Test Methods, 1971, Wiley-Interscience

McGounagle, Warren J., Nondestructive Testing

Metals Handbook, Volume 11, Nondestructive Inspection and Quality Control, American Society for Metals

Nondestructive Testing Handbook, edited by Robert C. McMaster, Ronald Press, 1959.

TEST

1. Sketch a permanent bar magnet, label its poles, and indicate the magnetic flux field pattern.

2. Describe the effect on magnetic fields by material discontinuities which makes possible detection of such discontinuities by magnetic particle testing.

3. Differentiate circular and longitudinal magnetic fields.

4. Define:
   a. residual magnetism

   b. coercive force

5. Name two types of current frequently used in magnetic particle examination and describe their relative penetrating capability:
   a.

   b.

6. Describe how an object is magnetized by a coil and state if the resultant field is circular or longitudinal

7. Describe or sketch the physical arrangements of a yoke and state its application.

8. Describe a "head shot" and state if the magnetic field is circular or longitudinal.

9. Describe or sketch direct induction prods and state its application.

10. State the application of central conductor magnetization and whether induced fields are circular or longitudinal.

11. Differentiate a mobile power unit and a stationary power unit.

12. Name four properties of concern with respect to magnetic particles and briefly describe desirable characteristics of each.

13. Briefly describe the dry method of application of magnetic particle inspection medium.

14. Briefly describe the wet method of application of magnetic particle inspection medium.

15. State the purpose of ultravoilet inspection lamps with respect to magnetic particle examination.

16. State four advantages of the magnetic particle test method.

17. State four disadvantages of the magnetic particle test method.